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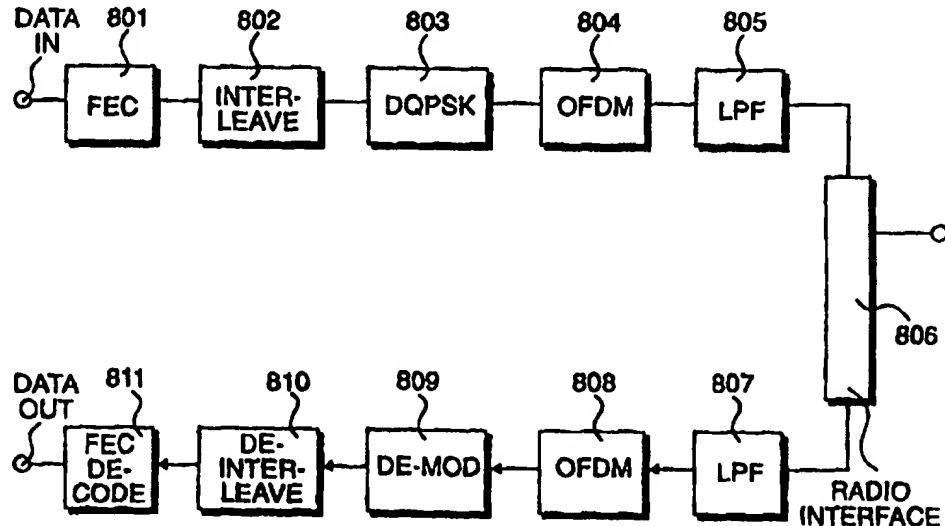
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| (51) International Patent Classification ⁶ : | A1 | (11) International Publication Number: | WO 98/02982 |
| H04B 7/26, H04J 4/00 | | (43) International Publication Date: | 22 January 1998 (22.01.98) |

| | | |
|---|--|--|
| (21) International Application Number: | PCT/IB97/00837 | (81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). |
| (22) International Filing Date: | 4 July 1997 (04.07.97) | |
| (30) Priority Data: | 9615030.5 17 July 1996 (17.07.96) GB | |
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(54) Title: MOBILE COMMUNICATIONS

(57) Abstract

Mobile communications apparatus (103) are arranged to transmit encoded speech in accordance with a first protocol and to transmit extended data in accordance with a second protocol. A wideband extension (601) is divided into time slots (TN0-TN7) which are substantially in phase with time slots for speech transmission. Signalling channels provided for speech are also used for establishing data calls within the extension. Extended data is conveyed by a process of orthogonal frequency division multiplexing (804). The multiplex is created by an inverse fast Fourier transform (903) and the transmission frequencies undergo a hopping sequence.



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MOBILE COMMUNICATIONS

The present invention relates to mobile communications arranged to transmit encoded data in accordance with a first protocol and to transmit 5 extended data in accordance with a second protocol.

Introduction

Radio transmission systems using frequency division multiplex and time division multiple access are known; an example being the GSM system 10 for mobile telephony. A primary band between 890 megahertz and 960 megahertz is allocated for GSM transmissions with each of these 25 megahertz bands being divided into a plurality of carriers, with a 200 kilohertz displacement between said carriers. This provides for a total of 122 usable carriers within the allocated bandwidth, each divided into a total of eight 15 transmission channels in the time domain, identified as time slot number 0 to time slot number 7. The eight time slot cycle occupies a time division multiple access (TDMA) frame of 4.615 milliseconds.

The size of finite time slots within a finite frequency band will determine the maximum theoretical data rate for a digitally transmitted signal. 20 Standard GSM allows a sufficient data rate for encoded speech signals to be transmitted and much work has been done in terms of minimizing data rates while minimizing signal degradation.

Increasingly, cellular radio communication is being used for the transmission of data as an alternative to encoded speech, possibly as a 25 direct modem link, a link to the Internet or as a facsimile transmission. GSM recommendations include provisions for data transmission in which, for example, the interleaving depth is increased so as to reduce the effect of errors due to fading. However, it is appreciated that a demand exists for higher rates of mobile data transmission which would require a higher 30 bandwidth than that provided by a conventional GSM channel, or a similar channel provided within a mobile telecommunications network essentially designed for the transmission of encoded speech.

According to a first aspect of the present invention, there is provided

mobile communications apparatus arranged to transmit first encoded data in accordance with a first protocol and to transmit extended data in accordance with a second protocol, comprising first transmission means for transmitting said first data over time slots within time division multiple access frames; and
5 second transmitting means for transmitting said extended data, wherein a second bandwidth for transmission of said extended data is divided into time slots substantially similar to said time slots for said first data.

In a preferred embodiment, the first transmitting means is arranged to transmit encoded speech data which may be in accordance with GSM
10 recommendations. Preferably, the second transmitting means is arranged to transmit said extended data within time slots substantially in phase with said time slots for said first data.

15 The extended data may represent machine readable data generated by a lap-top computer or similar device. Alternatively, the extended data may be used to convey better quality speech or any other type of encoded information such as graphical information or moving video etc.

20 Preferably, the second transmitting means is arranged to transmit extended data at a higher rate, than the data rate of said first protocol. Preferably, said second transmitting means is arranged to transmit extended data under a protocol less prone to errors than said first protocol.

In a preferred embodiment, the second transmitting means includes means for dividing a carrier channel into eight time slots within a TDMA frame. The dividing means may generate frames having a duration of between two milliseconds and eight milliseconds.

25 In a preferred embodiment, the first transmission means includes a signalling means arranged to communicate via signalling channels, wherein said signalling means are arranged to establish data calls for said second transmitting means.

30 The problem of fading associated with radio transmission is well documented. In addition to causing amplitude variations, fading caused by multi-path reflections also results in frequency selective fading in which, although some frequencies are attenuated, other frequencies are enhanced due to the accumulation of in-phase reflections.

The effect of these amplitude variations, in terms of signal degradation and distortion (resulting in data loss in the digital domain) are accommodated in GSM by providing interleaving and error correction. However, the problem becomes worse as signal bandwidth is increased. Under these circumstances, some parts of the signal itself, in the frequency domain, may suffer from constructive interference whereas other parts of the signal may suffer from destructive interference, possibly to the point of total extinction. Generally, frequency components close together will suffer similar variations and may therefore be considered as being well correlated. However, others which are further apart will be less well correlated and the correlation bandwidth may be considered as the frequency separation of signals that are correlated by a particular factor, usually taken as 0.9 or better. For a narrowband signal, frequency selective distortion is usually minimized if the bandwidth is less than the correlation bandwidth of the channel. Similarly, a signal which occupies a wider bandwidth (greater than the correlation bandwidth) will be subject to more distortion. Thus, providing a greater bandwidth for a particular transmission channel will not result in a pro rata increase in the data transfer capacity. As the bandwidth increases, the introduction of errors, due to multi-path transmission, will also increase. Thus, a straightforward approach of increasing channel bandwidth to provide broadband services results in less efficient use of the available total bandwidth being made, which in turn would place severe commercial limitations upon the exploitation of broadband services of this type.

As previously stated, the total theoretical data rate is determined by the bandwidth allocation in the frequency domain and time slot duration in the time domain. Thus, if it is not possible to increase data rate by increasing bandwidth, it should be possible to increase data rate by allocating more time slots to a particular channel or to allowing each channel to be provided with the full duration of each carrier, that is to say, by removing the time division multiple access component.

The TDMA aspect of digital cellular mobile transmission is also important in terms of channel identification, power saving and signalling. Thus, if wideband access is to be given to mobile users, it is preferable for

this access to be made compatible with existing schemes. Thus, in order to maintain this compatibility, it is preferable to maintain the time division multiple access component in frames similar to that used in encoded speech transmission such that, with this constraint in mind, it is then necessary to increase available frequency bandwidth within each of the allocated time slots.

In a preferred embodiment, the second transmitting means is arranged to transmit data by a process of orthogonal frequency division multiplexing. The second transmitting means may include processing means arranged to generate a parallel symbol from a plurality of output bits and to supply said parallel bits to an inverse Fourier transform process. Preferably, the processing means is arranged to transmit a plurality of OFDM symbols within a selected channel time slot.

According to a second aspect of the present invention, there is provided a mobile communication method arranged to transmit first encoded data in accordance with a first protocol and to transmit extended data in accordance with a second protocol, wherein said first data is transmitted over time slots within time division multiple access frames, comprising steps of allocating a second transmission bandwidth for said extended data transmission; and dividing said second bandwidth into time slots substantially similar to said first data time slots.

Preferably, the extended data is transmitted by a process of orthogonal frequency division multiplex.

In a preferred embodiment, channel time slots for extended data transmission are arranged to frequency hop over a plurality of transmission frequencies.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a cellular mobile environment facilitating data communication;

Figure 2 identifies the GSM primary band;

Figure 3 shows frequency division of the primary band shown in Figure 2;

Figure 4 shows the time division of carriers shown in Figure 3;

Figure 5 shows the assembly of time division frames into multi-frames and super frames;

Figure 6 illustrates the addition of wideband extension for data transmission, synchronized with speech transmission frames of the type shown in Figure 4;

Figure 7 is a schematic representation of the digital cellular telephone shown in Figure 1, including a processing assembly;

Figure 8 details the operation of the processing assembly shown in Figure 7, when encoding high rate data, including an orthogonal frequency division multiplexer and an orthogonal frequency division de-multiplexer;

Figure 9 details the multiplexer identified in Figure 8; and

Figure 10 details the de-multiplexer shown in Figure 8.

15 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention will now be described by way of example only with reference to the previously identified drawings. A digital data transmission environment is illustrated in Figure 1, in which a remote user may communicate with a central office computer 101 by means of a lap top computer 102 and a digital cellular telephone 103. The digital cellular telephone 103 is capable of operating in a first mode, wherein a speech channel is established in accordance with the GSM recommendations, such that 200 kilohertz frequency channels are divided into 8 time slots within a 4.615 millisecond frame. In addition, the digital cellular telephone is arranged to operate in a second mode, wherein the interleaving depth is increased for the transmission of machine readable data. Furthermore, the digital cellular telephone is arranged to operate in a third mode at an alternative frequency, where a greater bandwidth is provided to facilitate digital data transmission at 64 kilobits per second with low error rates. The ability to transmit data in this third mode has been identified as a wideband extension to the normal speech transmission characteristics.

During normal speech transmission or during wideband data transmission, the cellular telephone 103 is arranged to communicate with a

cellular base station 104 via a base station antenna 105. Cellular base station 104 is interfaced to a terrestrial network 106 which in turn allows signals to be transmitted to the office computer 101 via a suitable ISDN interface 107.

5 GSM specifications identify a primary band for transmission between 890 megahertz and 960 megahertz, as shown in Figure 2. Bandwidth region 201 represents a 25 megahertz region from 890 megahertz to 915 megahertz available for uplink transmissions from mobile telephones to base stations. Similarly, bandwidth 202 represents a 25 megahertz region from
10 935 megahertz to 960 megahertz available for downlink transmissions from base stations to mobile stations. The spectral region from 915 megahertz to 935 megahertz is not used, thereby providing a sufficient displacement between the uplink transmissions and the downlink transmissions so that said transmissions may be distinguished using analog filtering techniques.

15 Each 25 megahertz band 301, 302 is further divided in the frequency domain so as to allow a plurality of transmissions to occur, separated by frequency division multiplex. As shown in Figure 3, spectrum 301 is divided from 890 megahertz to 915 megahertz into individual bands of 200 kilohertz. Within each band, a carrier signal is modulated for the transmission of digital
20 data. Thus, within each frequency subdivision of spectrum 301 carrier signals are transmitted, identified as carrier 0, carrier 1, carrier 2, carrier 3, carrier 4 etc upto carrier 122, carrier 123, carrier 124. Each carrier may be modulated within its allocated band, thereby placing the major part of the signal energy within frequency allocations of 890 megahertz to 890.2 megahertz for carrier
25 0, 890.2 megahertz to 890.4 megahertz for carrier 1 etc. Each carrier signal, usually ranging from carrier 1 to carrier 122, may be modulated in response to digital signals which are in turn derived from a time division multiplex. The multiplex is derived from a total of 8 communication sources and a specific communications channel is defined in terms of its carrier frequency and its
30 time slot number (TN0 to TN7) within the time division multiplex. Conventional GSM transmissions therefore make use of frequency division multiplex, and time division multiple access within each of said frequency carriers.

The arrangement of time slots within frequency carrier bands are shown in Figure 4. Each carrier occupies a frequency band of 200 kilohertz and are shown positioned one above the other vertically. Each frequency band of 200 kilohertz is then subdivided into time slot numbers comprising 5 TN0, TN1, TN2, TN3, TN4, TN5, TN6 and TN7 displayed horizontally in Figure 4. An eight time slot cycle represents a TDMA frame of 4.615 milliseconds. Within each carrier frequency the time slots are synchronized, that is to say, the time slot boundaries are coincident, as required in order to allow frequency hopping to be achieved. A specific channel is defined in 10 terms of its time slot number within a particular carrier frequency, thereby giving a total of 8×122 possible communication channels. When frequency hopping occurs, transmission is retained within a particular time slot number but with the transmission frequency following a cycle of 64 possible carrier frequencies selected on a frame-by-frame basis. Thus, a particular frequency 15 is maintained for the duration of a frame, whereafter the next frequency in the frequency hopping cycle is selected for the next frame transmission.

The TDMA frame 501 of 4.615 milliseconds is illustrated in Figure 5. These frames are grouped into units of 51 frames to produce a multi-frame of 20 51 frames as shown at 502, having a duration of 235 milliseconds. These multi-frames are further grouped into super frames as shown at 503 consisting of 26 multi-frames resulting in a super frame duration of 6.12 seconds. Control information is broadcast from each base station thereby allowing mobile stations to select a preferred base station for communication purposes. Control information of this type is transmitted on a specific channel 25 for each base station in the network, with duplication only occurring when interference is not possible. Time slot number 0 is selected for control information on a specific channel for each base station, referred to as the beacon frequency. The information contained within this control channel provides for channel allocation allowing calls to be established within the standard speech encoded channels of conventional GSM. In addition, this 30 information is also used to establish wideband connections using alternative but related modulation techniques.

The top end of a GSM primary band downlink spectrum 202 is

illustrated in Figure 6. As previously stated, each carrier channel, such as channel 122, occupies a total bandwidth of 200 kilohertz allowing encoded speech to be transmitted with a tolerable degree of signal degradation. In accordance with the signalling protocols, a particular transmission channel is
5 identified as belonging to a particular carrier and having a particular time slot number within said carrier.

In addition to the transmission of encoded speech, it is also possible for low bandwidth data to be transmitted within one of the 200 kilohertz time slots. Furthermore, the system is provided with a third mode of operation in
10 which wideband data transmission takes place in a further area of the spectrum, identified as a wideband extension. The bottom of a typical wideband extension 601 is illustrated in Figure 6.

The time slots of the wideband extension TN0 to TN7 are synchronized to similar time slots of the conventional band 202. Thus, it is
15 possible for signalling information, carried in the broadcast control channel (BCCH) to be used to establish communications using the wideband extension. In this way, it is not necessary to provide an additional signalling system for the wideband transmissions.

The wideband extension 601 is divided into a plurality of wideband carriers WB0, WB1, WB2 etc. The number of carriers contained within a particular extension and the bandwidth allocated to each extension will depend on the data rates required. In this example, each wideband carrier is allocated a bandwidth of one megahertz and the system is arranged to provide a high quality digital link, compatible with ISDN transmissions, of 64 kilobits per second. Thus, each time slot within each wideband carrier provides sufficient bandwidth for a single-duplex 64 kilobits per second data stream to be transmitted as an uplink communication or a downlink communication. Thus, to establish full duplex communication of 64 kilobits per second, an uplink time slot is selected from a first wideband extension
25 spectrum, with a second similar spectrum being provided for similar downlink communications.
30

Digital cellular telephone 103 is shown schematically in Figure 7. A speech encoder 701 receives analog speech signals from a microphone 702

and supplies similar signals to a loud speaker 703. Speech encoder 701 performs analog to digital conversion and speech encoding, resulting in a digital bit stream being supplied to a digital signal processing assembly 704. The digital signal processing assembly 704 also communicates with the laptop computer 102 over an interface 705. The processing assembly 704 is provided with a selector, shown schematically as switch 706, allowing a first mode of operation to be selected, for normal encoded speech transmission, a second mode of operation to be selected for data transmission within speech channels and a third mode of operation to be selected for high bandwidth data transmission using wideband extensions.

The digital signal processing assembly 704 includes programmable components and is therefore configurable in response to program instructions. Its operation in said third mode is illustrated schematically in Figure 8. Data received from computer 102 is supplied to process 801 arranged to perform forward error correction (FEC). This increases the data rate by approximately three times but adds protection against errors introduced during transmission. The FEC encoded bit stream is supplied to an interleaving process 802 which distributes the coded bits over a plurality of transmission frames so as to distribute any burst errors thereby allowing the lost data to be reconstituted during error correction at the receiver. After interleaving, data is supplied to a differential quadrature phase shift keying process 803 which in turn supplies signals to an orthogonal frequency division multiplexing process 804. The output from multiplexing process 804 is supplied to a radio interface 806 via a low pass filtering process 805.

A similar arrangement is provided on the receiving side. Signals received by radio interface 806 are supplied to a low pass filtering process 807 which in turn supplies data to an orthogonal frequency demultiplexor 808. Demodulation is then effected by process 809 which in turn supplies interleaved data to de-interleaving process 810 so that encoded data may be supplied to the an FEC de-coding process 811.

At cellular base stations, such as station 104, the process is more complicated, in that the radio interface would be arranged to communicate with a plurality of coding and decoding channels, with channels

communicating on a common channel-frequency being displaced within the time division multiple access frame. Thus, wideband transmission takes place by firstly dividing the wideband spectrum into a plurality of carrier signals. These carrier signals are then further sub-divided within the time domain to provide eight time slots compatible with conventional GSM. Thereafter, data transmission takes place within each of these time slots by a process of orthogonal division multiplexing, thereby effectively transmitting the encoded digital data over a plurality of sub-carriers within the carrier bandwidth.

Orthogonal frequency division multiplexing allows data to be transmitted over a plurality of sub-carriers, where said sub-carriers are relatively close together compared to conventional frequency divisional multiplexing techniques. Sub-carriers are harmonically related and arranged such that they maintain an orthogonal phasal relationship. In this way, it is possible to demodulate the signals and retrieve the individual data streams.

A plurality of in-phase signals having a harmonic relationship is equivalent to one complex signal divided into its frequency components. The process of transforming a time related signal into representations of its frequency components is known in the art as a Fourier transform. Furthermore, it is possible to perform a fast Fourier transform (FFT) in the digital domain, allowing transformations to be made between time related signals and frequency related signals in real time.

OFDM process 804 is shown schematically in Figure 9. The QPSK symbols produced by the modulator 803 are supplied to a serial to parallel convertor 901. In this example, 168 input QPSK symbols are buffered in the serial to parallel converter to produce a 336 bit word on bus 902. This parallel word is used to modulate 168 orthogonal sub-carriers and as such may be treated as representations of harmonic amplitudes. These values are therefore supplied to an inverse fast Fourier transform process 903 arranged to take these individual representation of harmonic amplitudes and to produce a time related signal over a predetermined duration. At the receiver, this time based signal is supplied to a digital signal processor configured to perform a fast Fourier transform process from which individual amplitude levels for each harmonic are determined, thereby allowing the original input

data word to be reconstituted.

In accordance with the established protocols of OFDM, the input parallel word conveyed on bus 902 is referred to as a symbol and in this example, three time based signals are transmitted during each time slot,
5 allowing three OFDM symbols to be reconfigured within each of said time slots.

With a channel spacing of one megahertz, a sub-carrier spacing of 3.5 kilohertz is provided for the transmission of the orthogonal sub-carriers. A guard time interval of 0.005 milliseconds is provided on either side of the
10 transmitted OFDM symbol, to give a total duration of 0.192 milliseconds. The guard time interval of 0.005 milliseconds is determined by time guard process 904 arranged to activate switching process 905. The output from switching process 905 is supplied to a digital to analog converter 906.

In order for the individual OFDM symbols to be demodulated at the
15 receiver, it is necessary to place guards around the portion of the signal being transmitted. The IFFT system 903 is therefore arranged to receive carrier guards, each placed to a value of zero, making up a total of 256 inputs.

OFDM de-multiplexer 806 is detailed in Figure 10. An incoming
20 channel is identified by radio interface 806, resulting in a multiplexed OFDM symbol being supplied to OFDM modulator 808 via a low pass filter 807. The signal received from low pass filter 807 is sampled by an analog to digital convertor 1001, resulting in a stream of samples being supplied to a fast Fourier transform process 1003 via a time guard removal process 1002. The
25 fast Fourier transform process 1002 analyses the incoming samples to produce representations of harmonics, supplied as an OFDM symbols to parallel to serial convertor 1005 via a buffer 1004. Buffer 1004 is arranged to remove the front and rear guard sub-carriers, introduced by the coding process shown in Figure 9. The parallel to serial convertor 1005 receives the
30 parallel word and converts this into HQPSK symbols for the DQPSK demodulator 807. Within each time slot, three symbols are converted by converter 1001, transformed by the FFT 1003 and converted by parallel to serial convertor 1005. Thus, within each time slot, 3 OFDM symbols are

received.

In the embodiment disclosed, narrowband speech data is transmitted in the primary GSM band. In an alternative embodiment a different bandwidth is used for the narrowband signal, including narrowband data, which may be around 2 GHz or within the band designated for UMTS.

In a preferred embodiment, the TDMA frames for the narrowband speech and the data extension are synchronized although in an alternative embodiment they may not be synchronized. Such a situation may arise when the narrowband carriers are not being used.

In the preferred embodiment, different frequencies are used for bi-directional data transfer. In an alternative embodiment, a transmission by time division duplex is possible, such that uplink and downlink transmissions employ the same frequency and are only separated in the time domain.

CLAIMS

5 1. Mobile communications apparatus arranged to transmit first encoded data in accordance with a first protocol and to transmit extended data in accordance with a second protocol, comprising
 first transmission means for transmitting said first data over time slots within time division multiple access frames; and
 second transmitting means for transmitting said extended data, wherein a second bandwidth for transmission of said extended data is divided into time slots substantially similar to said time slots for said first data.

10

15 2. Apparatus according to Claim 1, wherein said first transmitting means for transmitting said first data is arranged to transmit encoded speech data.

20 3. Apparatus according to Claim 2, wherein said first transmission means is arranged to transmit said first data encoded in accordance with GSM recommendations.

25 4. Apparatus according to any of Claims 1 to 3, wherein said second transmitting means is arranged to transmit said extended data within time slots substantially in phase with said time slots for said first data.

30 5. Apparatus according to Claim 4, wherein said first transmission means and said second transmitting means transmit data within frames having eight time slots.

35 6. Apparatus according to any of Claims 1 to 5, wherein said second transmitting means is arranged to transmit extended data at a second date rate, higher than the data rate for the transmission of said first data.

40 7. Apparatus according to any of Claims 1 to 6, wherein said second transmitting means is arranged to transmit data in accordance with a

protocol that is less prone to errors than said first protocol.

8. Apparatus according to Claims 1 to 7, wherein said first transmission means includes signalling means arranged to communicate via signalling channels, wherein said signalling means are arranged to establish data calls for said second transmitting means.

9. Apparatus according to any of Claims 1 to 8, wherein said second transmitting means is arranged to transmit data by a process of orthogonal frequency division multiplexing.

10. Apparatus according to Claim 9, wherein said second transmitting means includes processing means arranged to perform an inverse Fourier transform process upon a plurality of data bits.

11. Apparatus according to Claim 10, wherein said processing means is arranged to transmit a plurality of OFDM symbols within a selected channel time slot.

20 12. Apparatus according to any of Claims 1 to 11, wherein said second transmitting means is arranged to transmit encoded symbols at various transmission frequencies in accordance with a frequency hopping sequence.

25 13. A mobile communications method arranged to transmit first encoded data in accordance with a first protocol and to transmit extended data in accordance with a second protocol, wherein said first data is transmitted over time slots within time division multiple access frames, comprising steps of

30 allocating a second transmission bandwidth for said extended data transmission; and

dividing said second bandwidth into time slots substantially similar to said first data time slots.

14. A method according to Claim 13, wherein said first encoded data represents encoded speech data.

5 15. A method according to Claim 13 or Claim 14, wherein said first data is encoded in accordance with GSM recommendations.

10 16. A method according to any of Claims 13 to 15, wherein said extended data is transmitted within time slots substantially in phase with said time slots for said first data.

17. A method according to Claim 16, wherein said first data and said second data are transmitted within frames having eight time slots.

15 18. A method according to any of Claims 13 to 17, wherein the rate of data transmission for said second data is higher than the rate of transmission for said first data.

20 19. A method according to any of Claims 13 to 18, wherein the second protocol is less prone to the introduction of errors than said first protocol.

25 20. A method according to any of Claims 13 to 19, wherein said first data protocol includes an associated signalling channel and said signalling channel is arranged to establish data calls for data transmitted in accordance with said second protocol.

30 21. A method according to any of Claims 13 to 20, wherein said second data is transmitted by a process of orthogonal frequency division multiplexing.

22. A method according to Claim 21, wherein an orthogonal frequency division multiplex is generated by an inverse Fourier transform

process.

23. A method according to Claim 21, wherein a plurality of OFDM symbols are transmittable within each channel time slot.

5

24. A method according to any of Claims 13 to 23, wherein channel time slots for said extended data transmission are arranged to frequency hop over a plurality of transmission frequencies.

10

25. Apparatus for mobile communications substantially as herein described with reference to the accompanying drawings.

26. A method of mobile communication substantially as herein described with reference to the accompanying drawings.

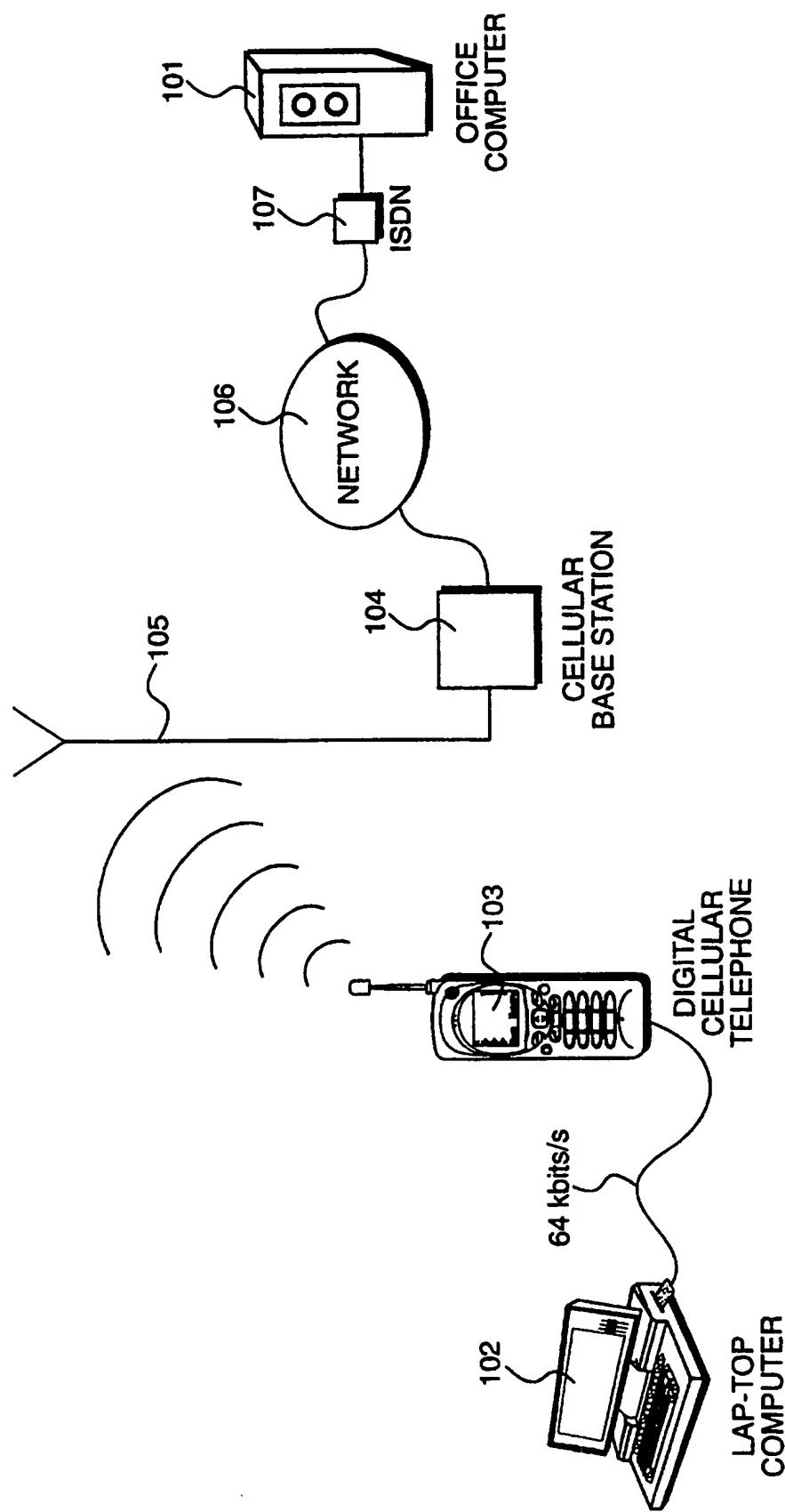


Figure 1

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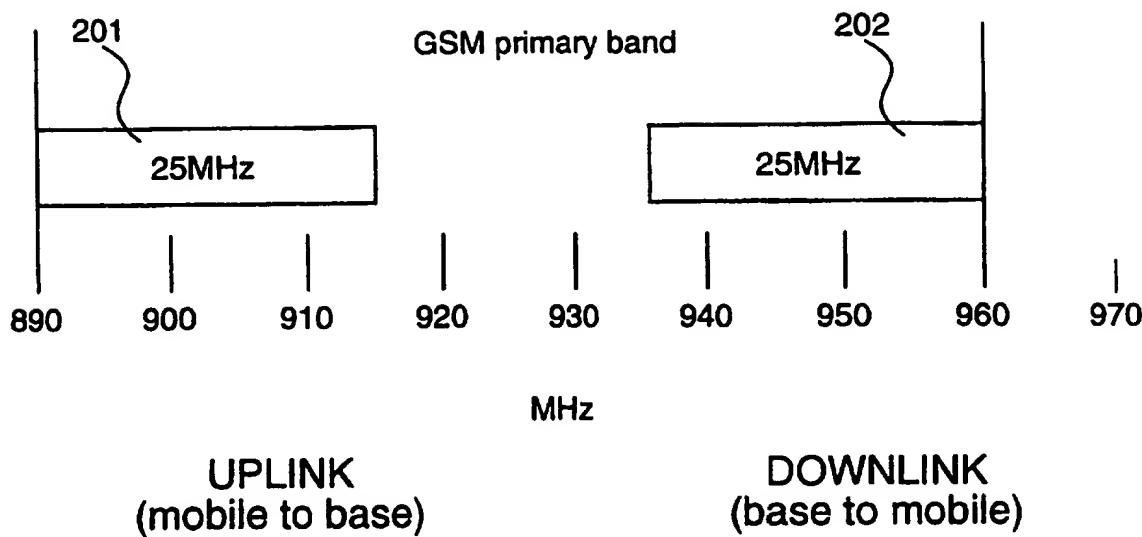


Figure 2

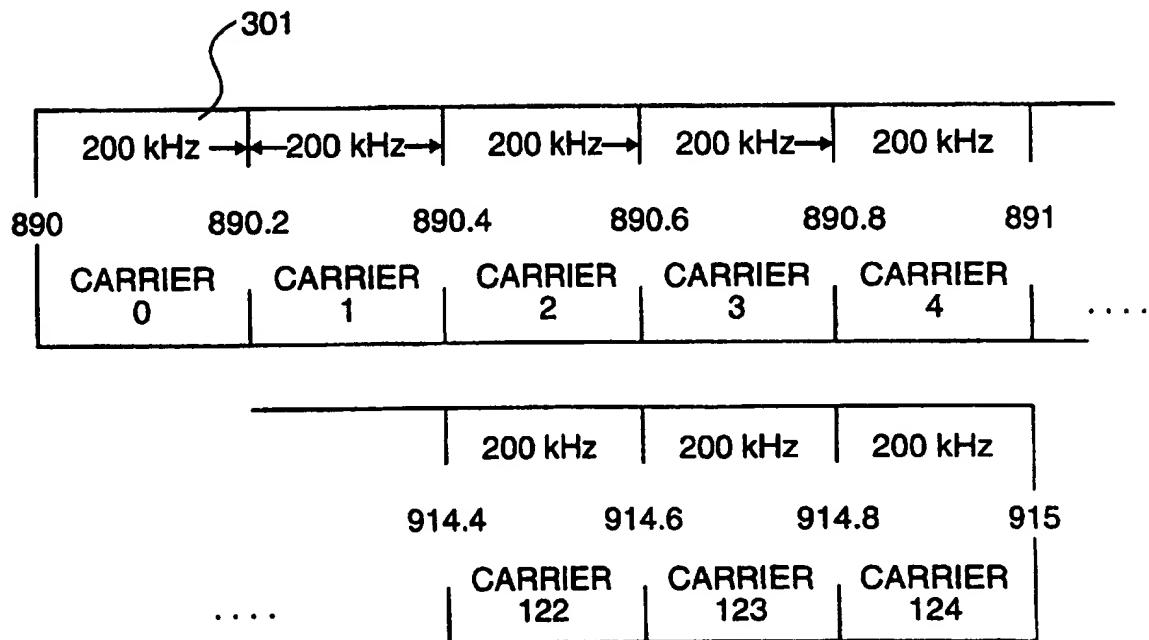


Figure 3

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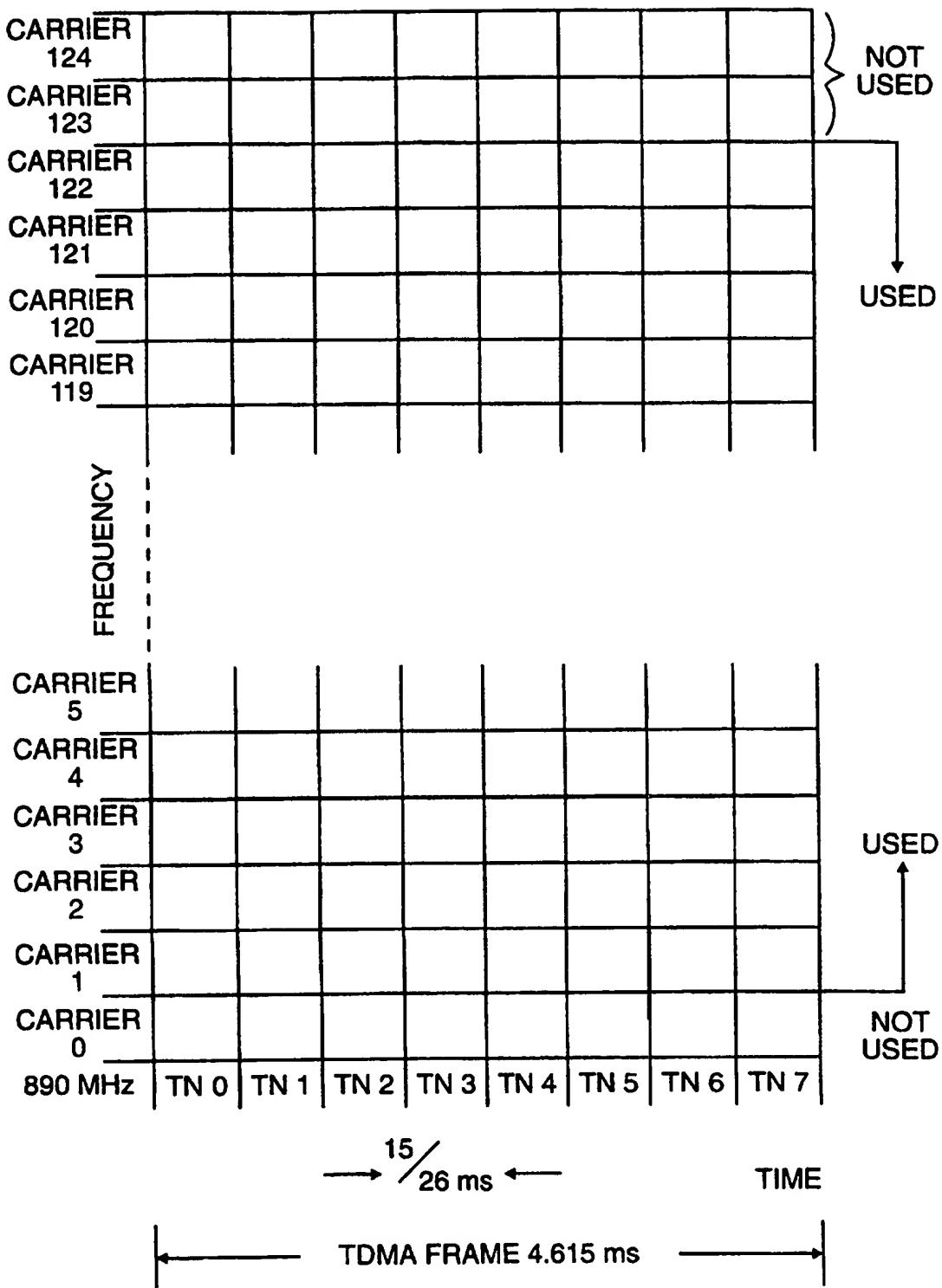


Figure 4

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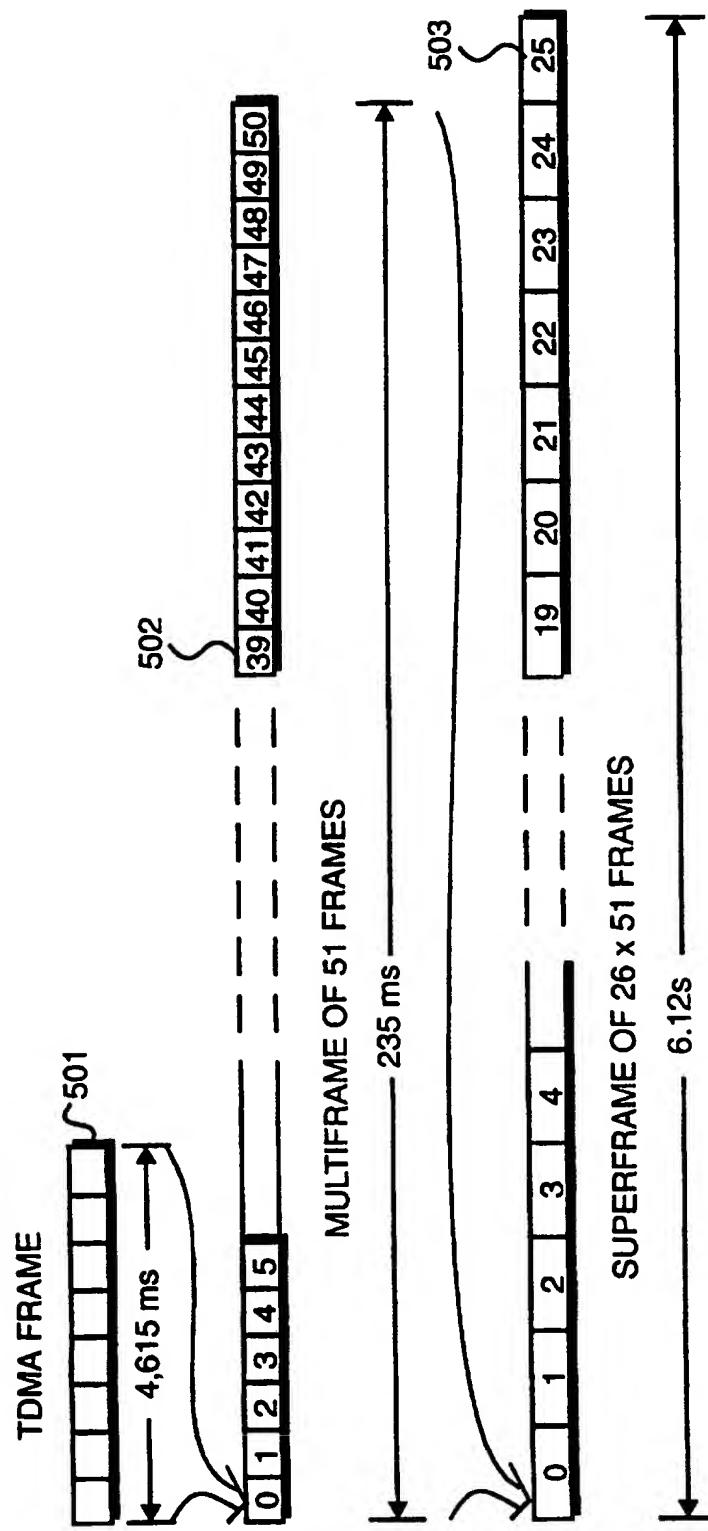
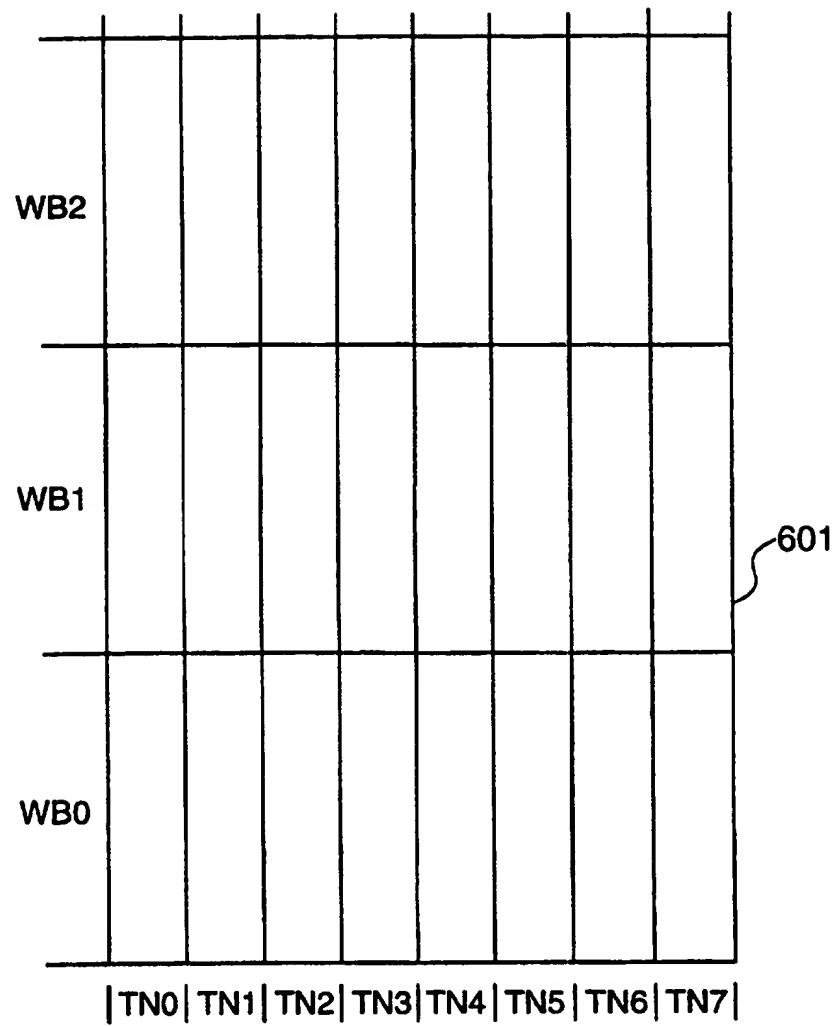


Figure 5

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960 MHz

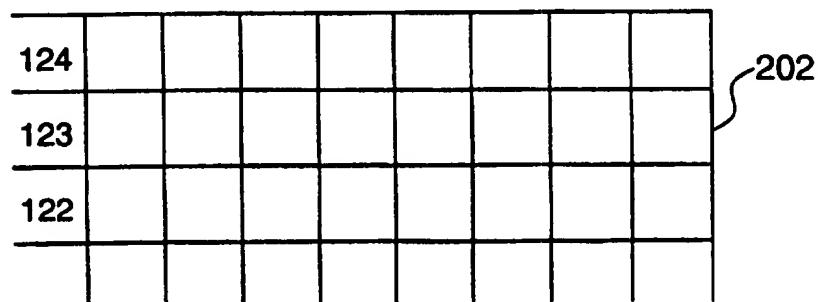


Figure 6

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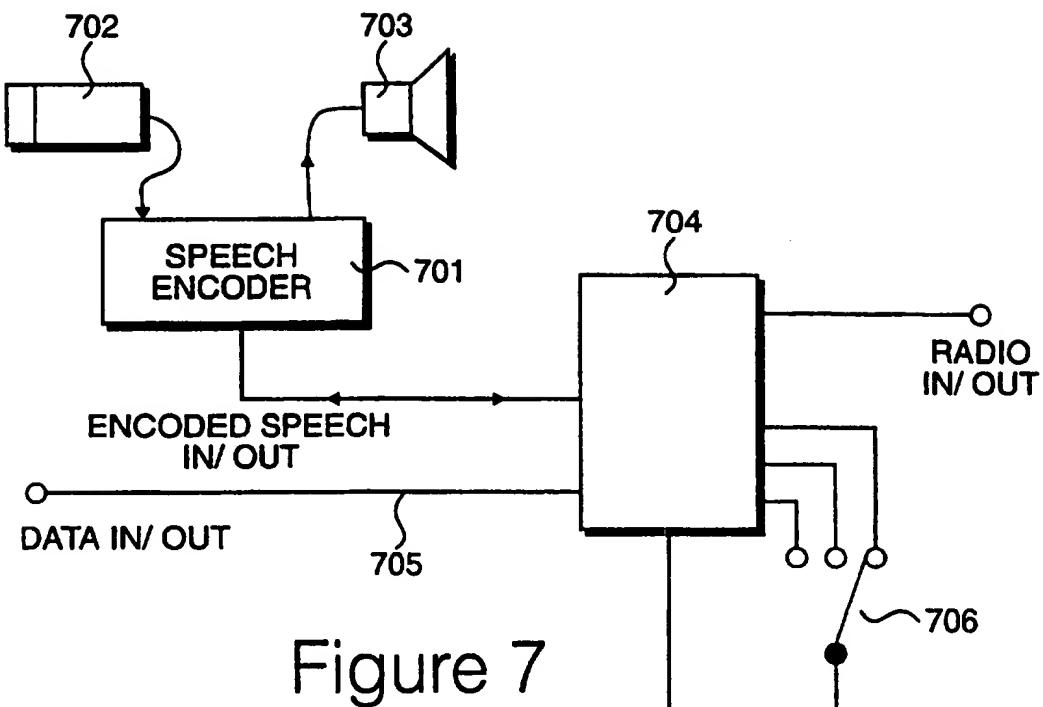


Figure 7

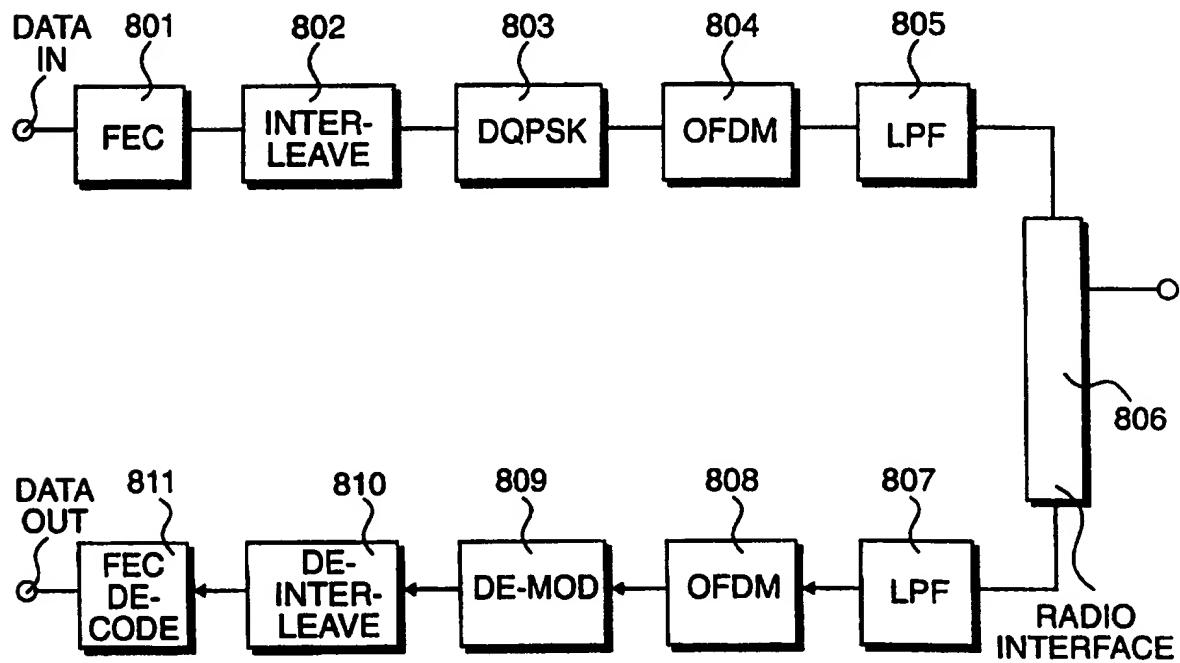


Figure 8

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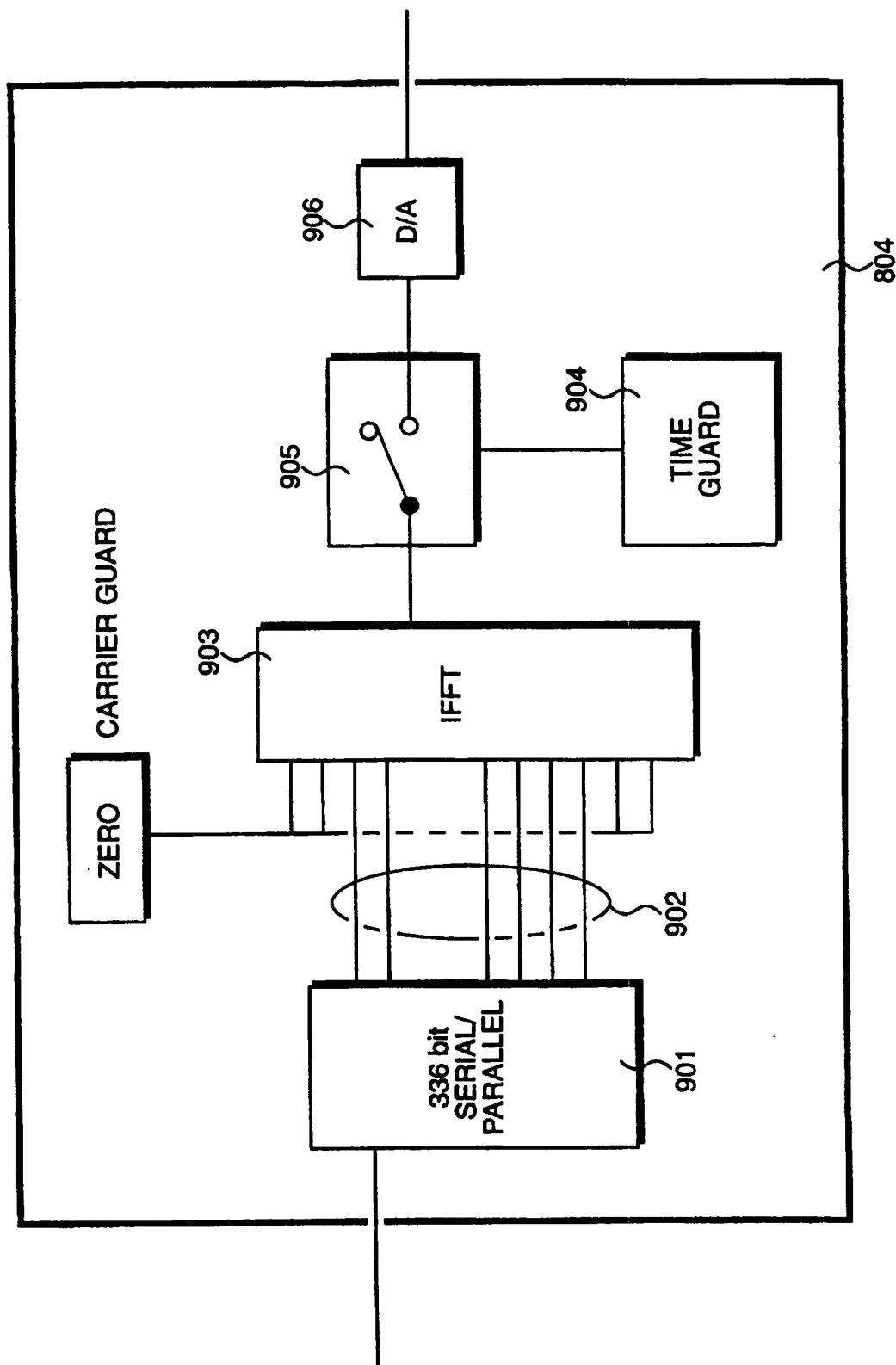


Figure 9

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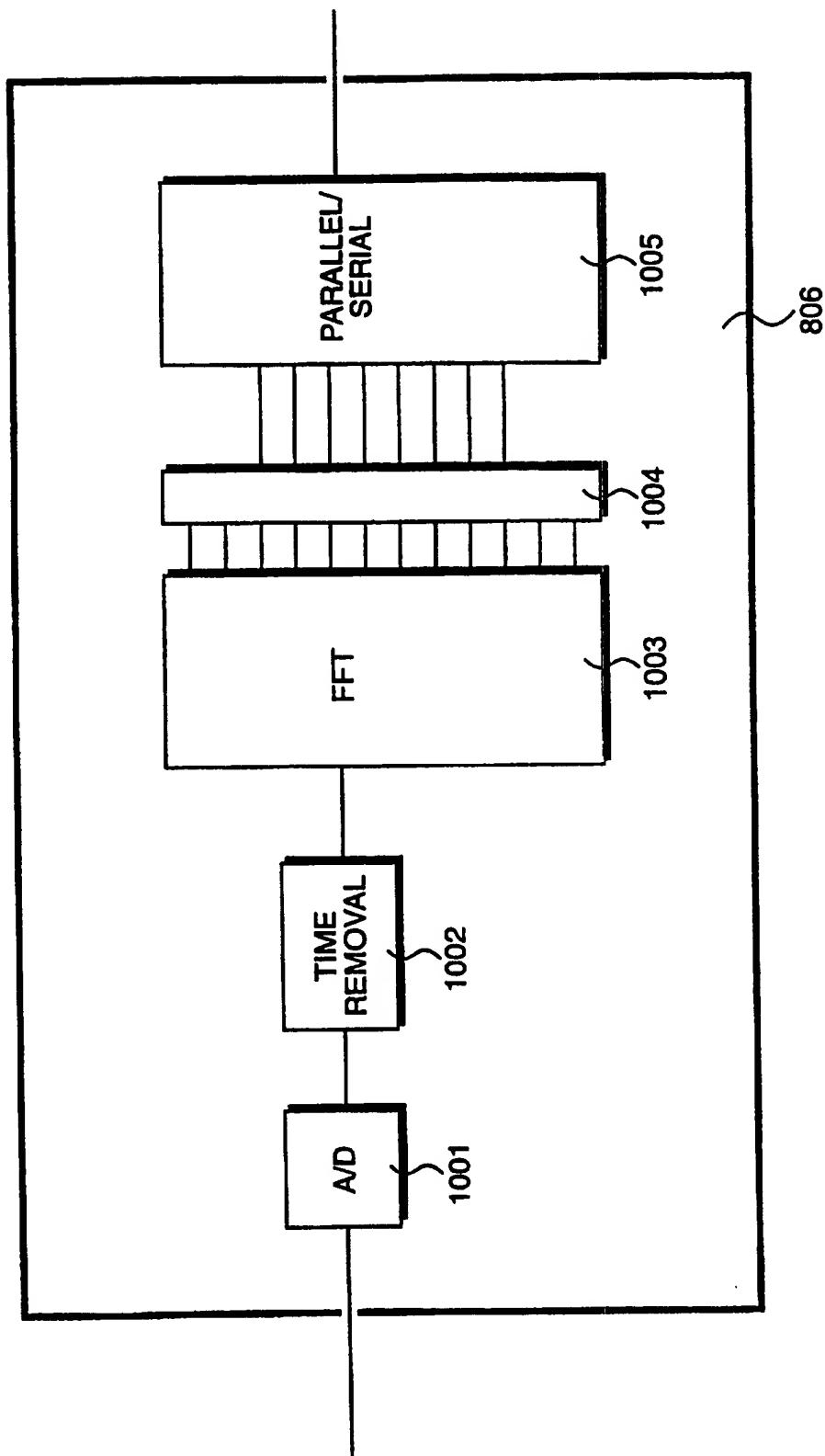


Figure 10

INTERNATIONAL SEARCH REPORT

Intern. Application No

PCT/IB 97/00837

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 6 H04B7/26 H04J4/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHEDMinimum documentation searched (classification system followed by classification symbols)
 IPC 6 H04B H04J H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|------------|--|-------------------------|
| X | US 5 134 615 A (FREEBURG THOMAS A ET AL) 28 July 1992 see figures 1,3 | 1,13 |
| A | see column 1, line 64 - column 4, line 12 see claim 1 --- | 2-6, 14-18, 25,26 |
| X | US 5 428 613 A (SPIOTTA MARK G ET AL) 27 June 1995 see the whole document --- | 1,2,13, 14 |
| A | EP 0 595 637 A (NOKIA MOBILE PHONES LTD) 4 May 1994 see column 1, line 11 - column 4, line 24 --- | 1-3,6,7, 12 -/- |



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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1

Date of the actual completion of the international search

30 September 1997

Date of mailing of the international search report

13.10.97

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INTERNATIONAL SEARCH REPORT

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|------------|--|----------------------------------|
| A | <p>EP 0 211 460 A (PHILIPS PATENTVERWALTUNG ; PHILIPS NV (NL)) 25 February 1987</p> <p>see column 3, line 45 - column 6, line 55 see column 10, line 51 - column 11, line 48 see figures 1,4</p> <p>---</p> | 1-6,9, 11, 13-18, 21,23 |
| A | <p>US 5 446 739 A (NAKANO MOTOHIRO ET AL) 29 August 1995</p> <p>see figure 1</p> <p>see column 2, line 59 - column 3, line 26 see column 4, line 26 - line 55 see column 6, line 47 - column 8, line 38 see claims 1-3</p> <p>---</p> | 1-6, 13-18 |
| P,X | <p>WO 97 16000 A (OMNIPOINT CORP) 1 May 1997</p> <p>see abstract</p> <p>see page 4, line 35 - page 6, line 18 see page 11, line 5 - page 13, line 23 see page 14, line 19 - page 16, line 28 see page 38, line 34 - page 39, line 31 see claims 1-6; figures 1,3,4,6,13</p> <p>-----</p> | 1-5, 13-17, 25,26 |

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Information on patent family members

International Application No

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